A Preliminary Cross-Evaluation of Tropospheric Ozone from Aura OMI/MLS and DIAL Lidar Measurements During INTEX-B

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Tropospheric O_3 From OMI/MLS and DIAL During the INTEX-B Campaign (March 2006-May 2006)

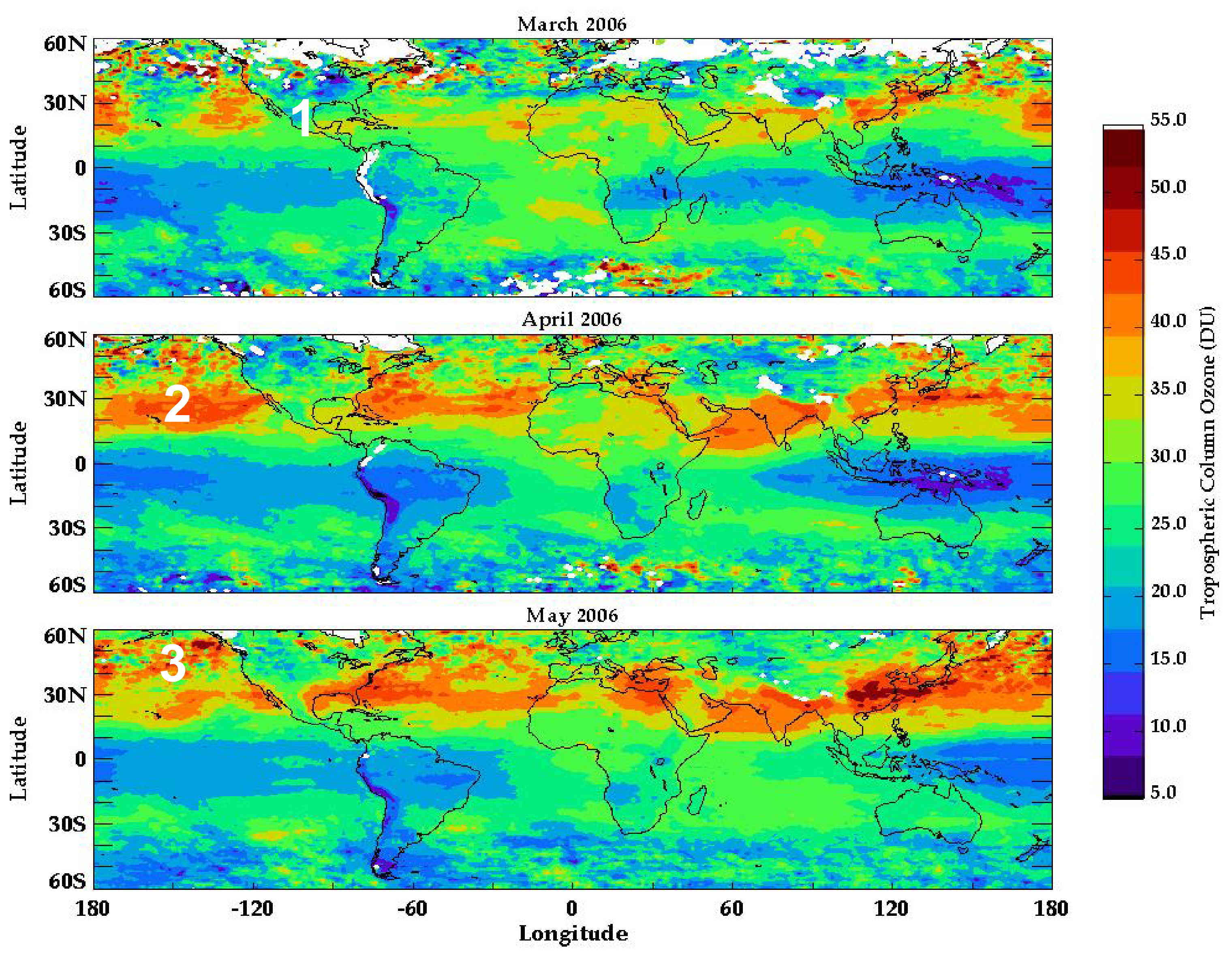
- Differential Absorption Lidar (DIAL) O_3 measurements (E. V. Browell, et al., 2006):
  (1) O_3 measured above and below the DC8 aircraft (in field data)
  (2) 60 m vertical sampling
  (3) O_3 number density converted to volume mixing ratio (VMR)

- Analysis of DIAL tropospheric O_3:
  (1) Daily tropospheric O_3 VMR binned to $1^o \times 1.25^o$ like OMI/MLS VMR
  (2) Used 150 ppbv O_3 chemical tropopause for DIAL
  (3) Used pressure/altitude climatology to estimate pressures for DIAL

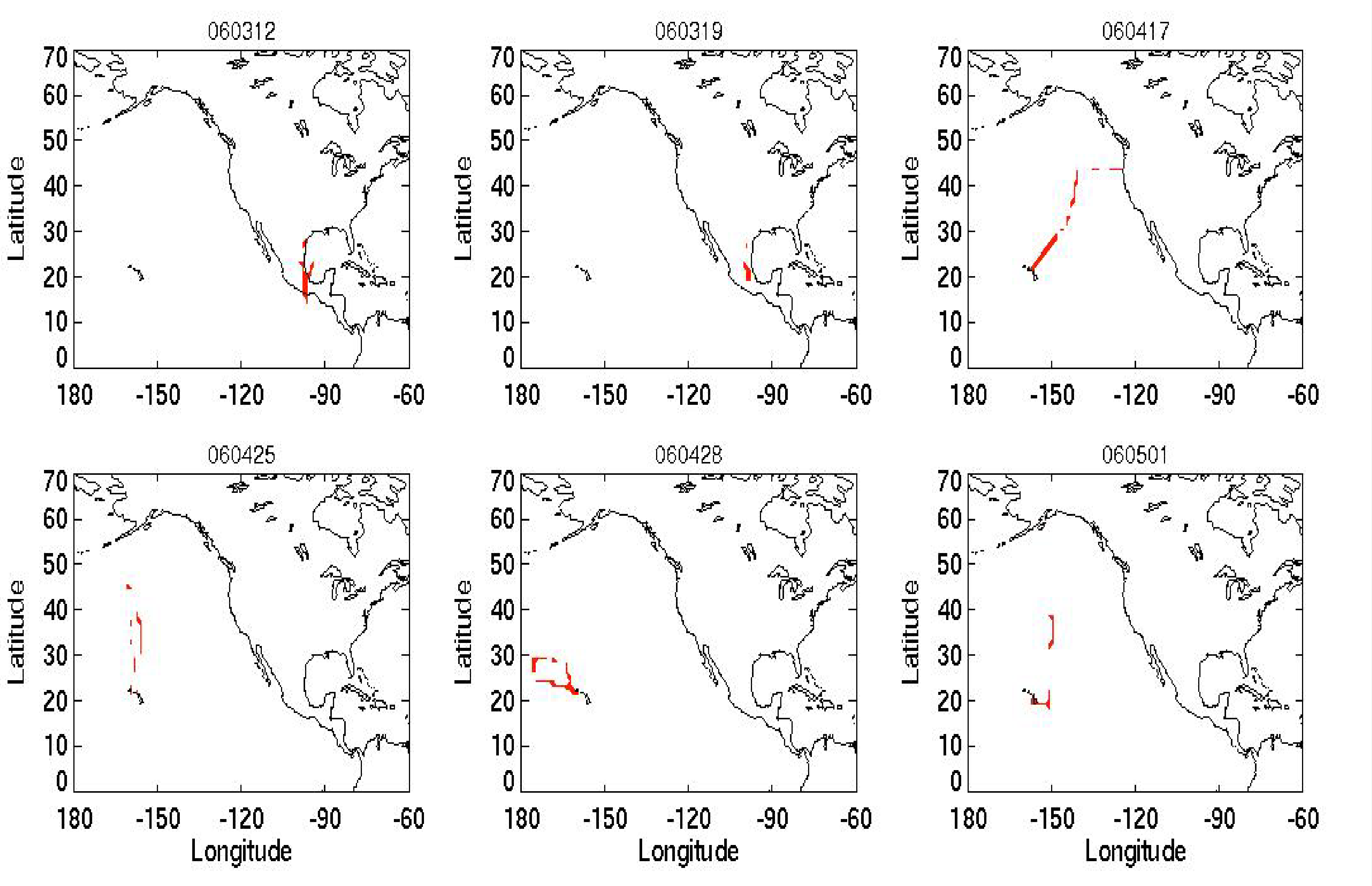
- Analysis of OMI/MLS tropospheric O_3:
  (1) Daily tropospheric O_3 pressure-weighted VMR
  (2) NCEP tropopause ≤ 150 hPa (WMO 2K/km def'n)
  (3) Cloud filtered (OMI reflectivity < 0.3)

There were three regional campaign phases of INTEX-B (next slide)

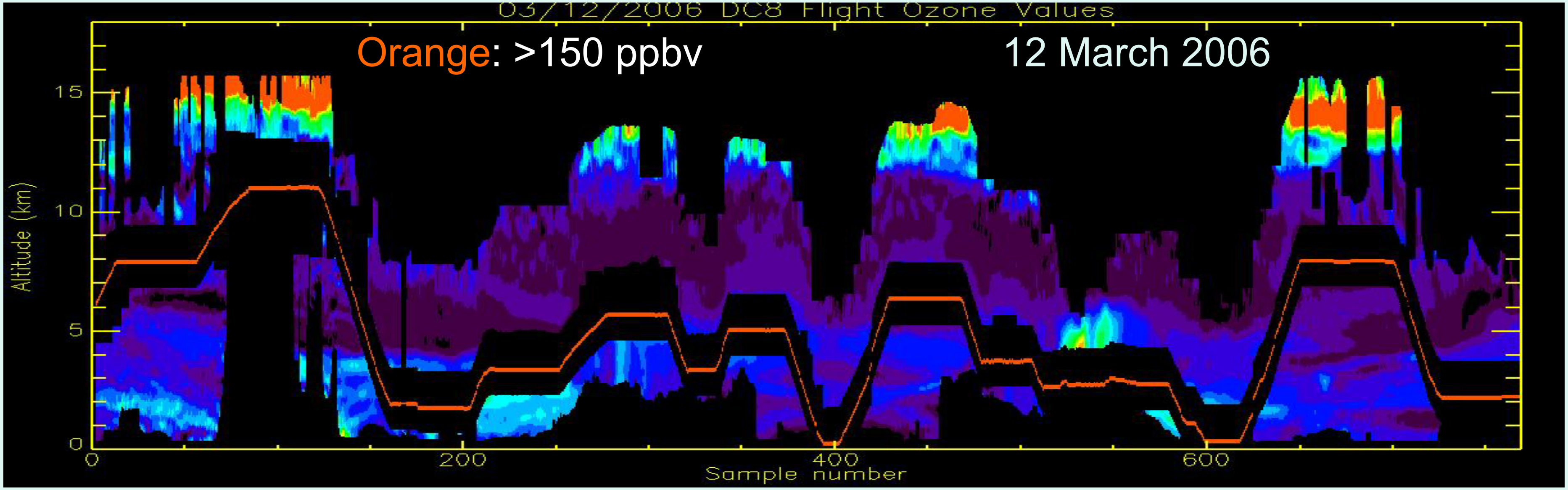
Three Regional Phases of the INTEX-B Campaign (March 2006-May 2006)

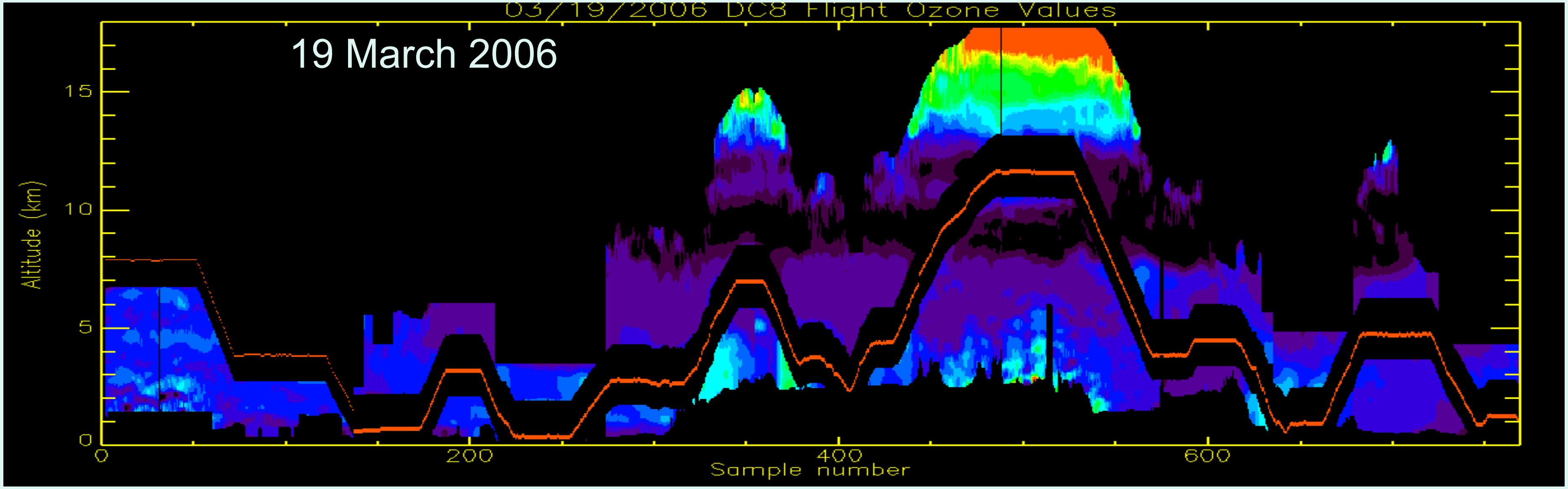


INTEX-B Flight Paths



Preliminary DIAL Aircraft O_3 Volume Mixing Ratio (E. Browell, et al., 2006)





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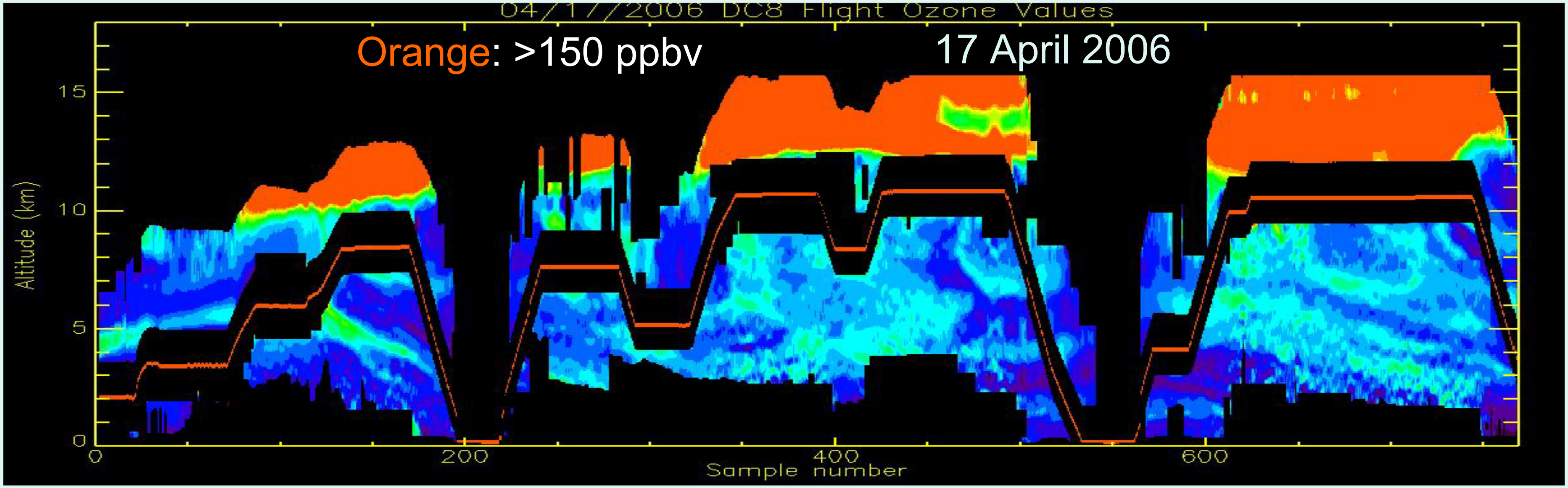
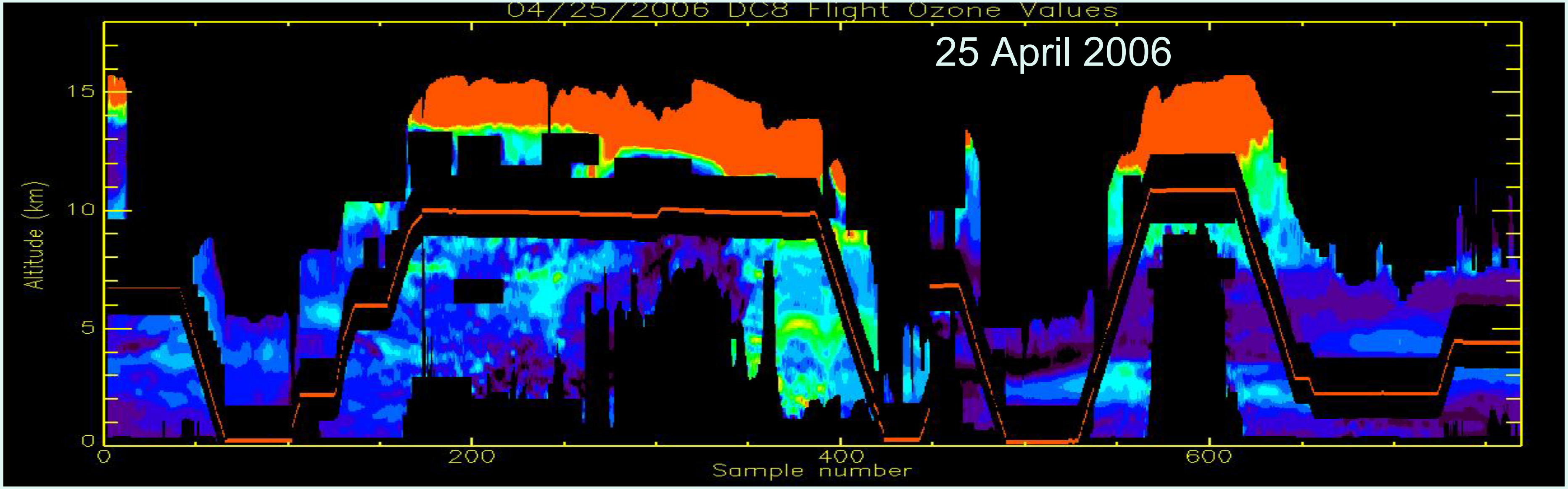
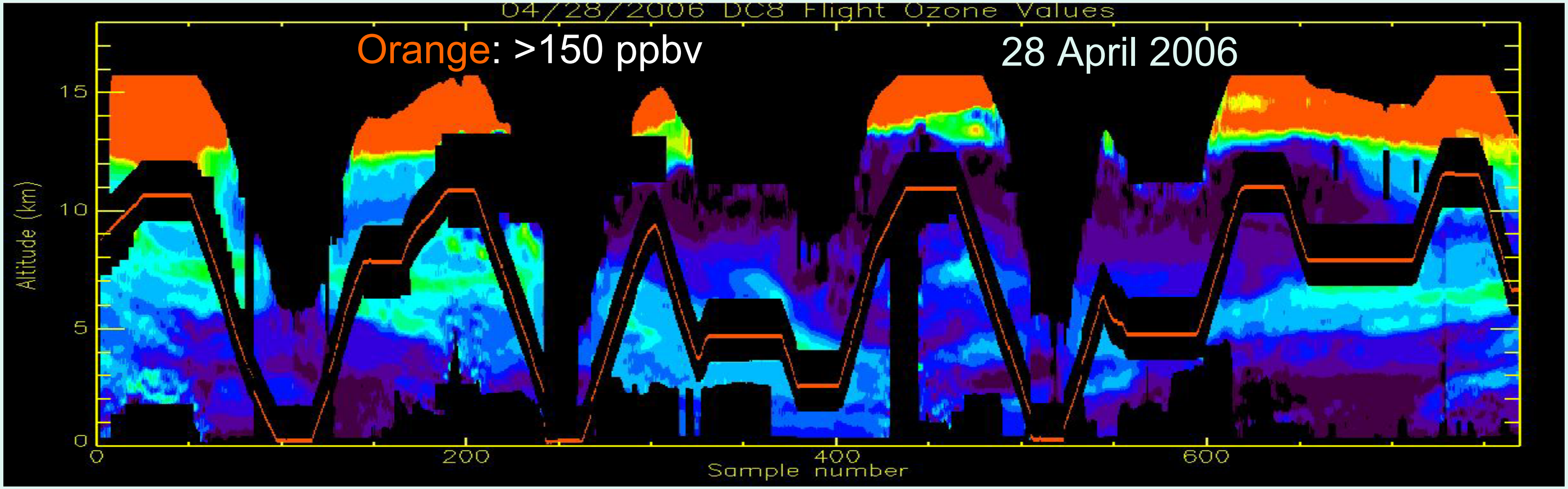
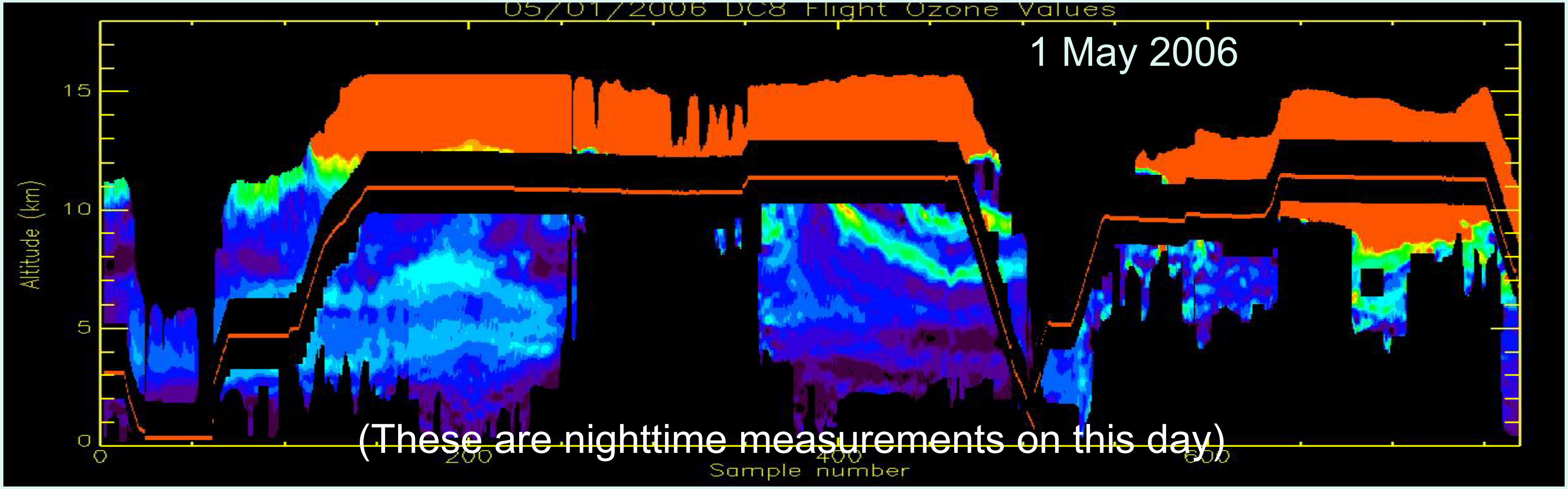




Preliminary DIAL Aircraft O_3 Volume Mixing Ratio (E. Browell, et al., 2006)





The Dobson Unit and Pressure-Averaged Mixing ratio

$$\text{Column Amount} = \Delta\Omega(\text{Dobson Units}) \approx 0.79 \int_{P1(hPa)}^{P2(hPa)} \chi(\text{ppmv}) \cdot dP_{ATM}(\text{hPa})$$

(One "Dobson Unit" $\equiv 2.69 \times 10^{20}$ molecules-m^{-2})

$$\text{Mean Mixing Ratio} = \langle \chi(\text{ppmv}) \rangle \approx 1.27 \cdot \frac{\Delta\Omega(\text{DU})}{P_2(\text{hPa}) - P_1(\text{hPa})}$$

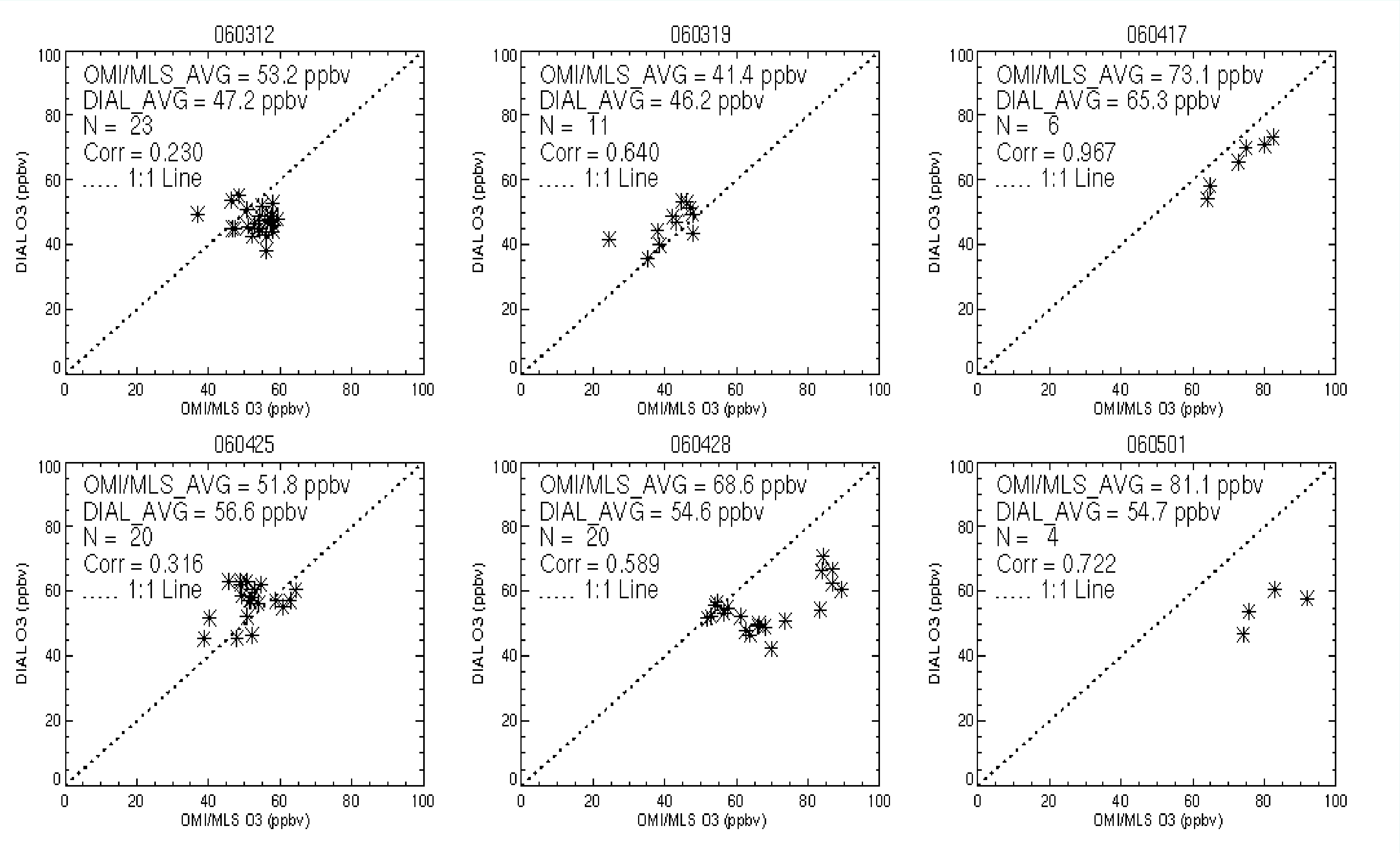
OMI/MLS

$$= 1.27 \frac{\int_{P1(hPa)}^{P2(hPa)} \chi(\text{ppmv}) \cdot dP_{ATM}}{\int_{P1(hPa)}^{P2(hPa)} dP_{ATM}}$$

DIAL

$$= 1.27 \cdot \frac{\sum_i \chi_i(\text{ppmv}) \cdot \Delta_i P(hPa)}{\sum_i \Delta_i P(hPa)}$$

OMI/MLS and DIAL Tropospheric Ozone (ppbv)



OMI/MLS Average = 61.5 ppbv

DIAL Average = 54.1 ppbv

CONCLUSIONS

- DIAL yields high vertical and spatial resolution of O_3 above and below aircraft along flight path (not measurable with satellite instruments)

- OMI/MLS and DIAL tropospheric O_3 comparisons utilized pressure-weighted volume mixing ratio

- Comparisons are encouraging: OMI/MLS and DIAL show clear positive correlations and mean values of interpreted O_3 VMR within 5-10 ppbv

TOMS Ozone Weighting Function is Proportional to Pressure Throughout Much of the Troposphere

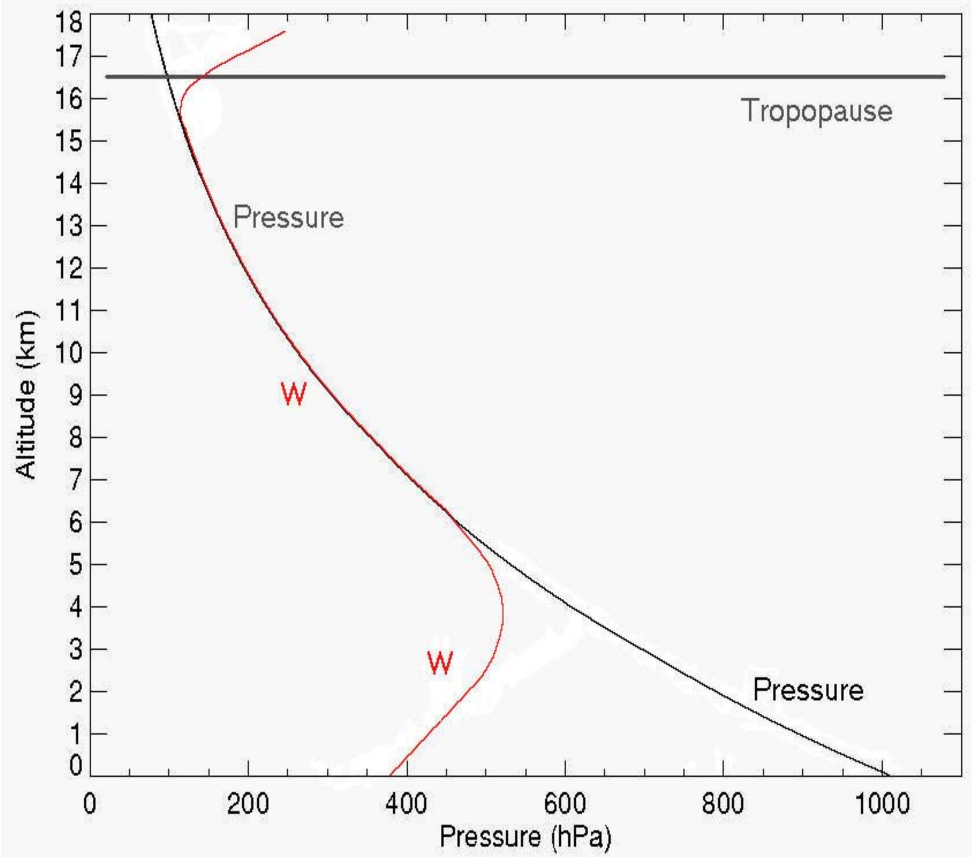
TOMS OZONE ALGORITHM

$$\Delta\Omega \propto \int_{P1}^{P2} \chi \cdot W \cdot d\ln P$$

$$(\Delta\Omega \propto \int_{P1}^{P2} \chi \cdot P \cdot d\ln P)$$

where

$\Delta\Omega$ = Column ozone
P = Pressure
χ = Ozone volume mixing ratio
W = Weighting function (averaging kernel)
C = Constant



Calculation of Column Amount for an Arbitrary Atmospheric Constituent

$\Delta\Omega$ = Column Amount (molecules-m^{-2})

$$\equiv \int_{z1}^{z2} n \cdot dz$$

$$= \int_{z1}^{z2} \chi \cdot n_{ATM} \cdot dz$$

$$= \int_{P1}^{P2} \chi \cdot n_{ATM} \cdot \frac{dP_{ATM}}{\rho_{ATM} g}$$

$$= \frac{N_A}{\mu_{ATM}} \int_{P1}^{P2} \chi \cdot \frac{dP_{ATM}}{g}$$

$$= \frac{N_A}{\mu_{ATM} < g >} \int_{P1}^{P2} \chi \cdot dP_{ATM} = \frac{N_A}{\mu_{ATM} < g >} \int_{P1}^{P2} \chi \cdot P_{ATM} \cdot d \ln P_{ATM}$$

where

z = Altitude (m)
n = Constituent number density (molecules-m^{-3})
n_{ATM} = Atmosphere number density (molecules-m^{-3})
χ = Constituent mixing ratio by unit volume
P_{ATM} = Atmospheric pressure (Pa$\leftrightarrow$N-m^{-2})
ρ_{ATM} = Atmospheric mass density (kg-m^{-3})
g = Acceleration of gravity (m-s^{-2}) ($\approx$9.807 m-s^{-2} at Earth's surface)
μ_{ATM} = Mean molecular weight of atmosphere ($\approx$29)
N_A = Avogadro's number (6.022×10^{26} molecules-kmol^{-1})

Column Amount Also Applies to the Total Atmosphere for Measuring Mass Between Two Pressure Surfaces

For the total atmosphere ($\chi = 1$), $\Delta\Omega$ (molecules - m^{-2})

$$= \frac{N_A}{\mu_{ATM}} \int_{P1}^{P2} \chi \cdot \frac{dP_{ATM}}{g} = \frac{N_A}{\mu_{ATM} < g >} \int_{P_{ATM}=0}^{Psurface} dP_{ATM} = \frac{N_A}{\mu_{ATM} < g >} \cdot P_{surface}$$

$$\text{Mass of atmosphere (kg)} = \oiint_S \Delta\Omega \cdot \frac{\mu_{ATM}}{N_A} \cdot dS$$

$$= \left(\frac{P_{surface}}{< g >} \right)_{\substack{Surface \\ Area \\ Average}} \cdot 4\pi R^2$$

Examples:

Atmospheric mass of Earth: 5.2×10^{18} kg

Atmospheric mass of Saturn's satellite Titan: 9.4×10^{18} kg

(i.e., Titan's atmosphere ~ 80% more massive than Earth's atmosphere)